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Surveillance for WDM Systems Using Fiber Bragg Gratings

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ABSTRACT

This paper discusses the use of fiber Bragg gratings (FBG) for various surveillance applications on WDM networking elements and systems. The surveillance schemes are based on inserting FBGs at strategic locations along the systems to generate the monitoring signal. All these schemes are non-intrusive and require no additional light source for the monitoring function.

INTRODUCTION

The explosive demand in bandwidth-hungry Internet and multimedia applications has expedited the technology development of the wavelength division multiplexing (WDM) systems, which nowadays is capable of delivering Tb/s data stream in a single optical fiber. To ensure a reliable operation of these systems, performance monitoring is a must. A total or partial failure in the networking element/system should be detected promptly so that appropriate remedies can be executed to restore its operation.

The use of fiber Bragg grating (FBG) [1] as a narrow band filter/reflector has found many applications in WDM systems [2], including wavelength add-drop (de)multiplexers, fiber sensors, dispersion compensator, etc. Here, we will discuss our previous work in extending the use of FBGs in surveillance for various WDM networking elements and systems.

SURVEILLANCE IN WDM SYSTEMS

(a) Point-to-Point Transmission Link

The major failure mechanism in a point-to-point WDM transmission link is either a failure in pump laser diode in the in-line amplifier or a break in the fiber link. By making use of the amplified spontaneous emission (ASE) from the Erbium doped fiber amplifier (EDFA) as the monitoring light source and a strategic placement of FBGs with distinct center reflection wavelengths at the EDFA inputs (Fig. 1), we have demonstrated a cost effective fault-monitoring scheme [3], capable of identifying the exact failed in-line amplifier and/or fiber break in real time. The fault information can be observed at the receiver end where the exact failed EDFA and/or broken fiber segment can be identified by the presence of an additional enhanced emission at the corresponding FBG wavelength.

(b) Add-Drop Branching Unit

The fault surveillance scheme described in (a) can be extended to realize a fault tolerant wavelength add-drop branching unit [4] for long-haul transmission link. Two FBGs with identical center reflection wavelength are inserted as shown (Fig. 2) in the branching unit. The first FBG is to drop a wavelength channel from the transmission link to the local network, and at the same time, generate the fault monitoring signal. Whereas the second one is to extract the fault monitoring signal and then add a new wavelength from the local network to the transmission link. The scheme can identify the exact failed pump laser diode within the branching unit and automatically restore the system operation by switching to the backup pump laser diode.

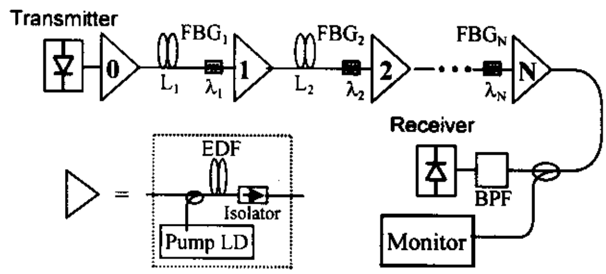

Fig. 1 Surveillance scheme for an amplified optical transmission system. (EDF: Erbium doped fiber; BPF: Bandpass filter)

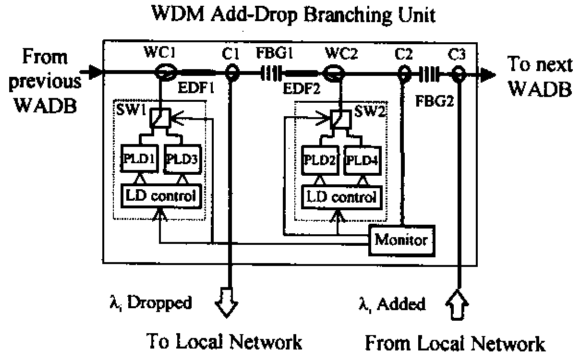

Fig. 2: Architecture of the proposed WDM add-drop branching unit (WADB) (PLD1&2: working pump laser diodes; PLD3&4: backup pump laser diodes; FBG1&2: fiber Bragg gratings; EDF1&2: erbium-doped fibers; SW1&2: 1×2 optical switches, C1-3: optical circulators; WC1&2: 980/1550nm WDM couplers)

(c) Optical Crossconnect

Failure in the switches in a dynamic optical cross-connect (OXC) will generate routing errors, leading to severe data loss. We have proposed and demonstrated an optical path supervisory scheme for an arrayed-waveguide-grating (AWG) based OXC (Fig. 3). The surveillance scheme requires a sweeping monitoring source which can be realized by feeding back the output ASE of the input optical amplifier to its input through a scanning Fabry-Perot filter centering at the unused portion of the ASE and sweeping at a unique frequency. The sweeping frequency will serve as an identification (ID) tag for all data wavelengths for a given input fiber.

At each OXC's output port, multiple FBGs are inserted to detect the ID tags which is located one free spectral range (FSR) away from the corresponding routed data wavelengths. By interpreting the ID, the source of the corresponding routed wavelength channel is identified. Such monitoring scheme requires no tapping off in the data wavelength, minimizing the loss in the data wavelength and preserving the data privacy.

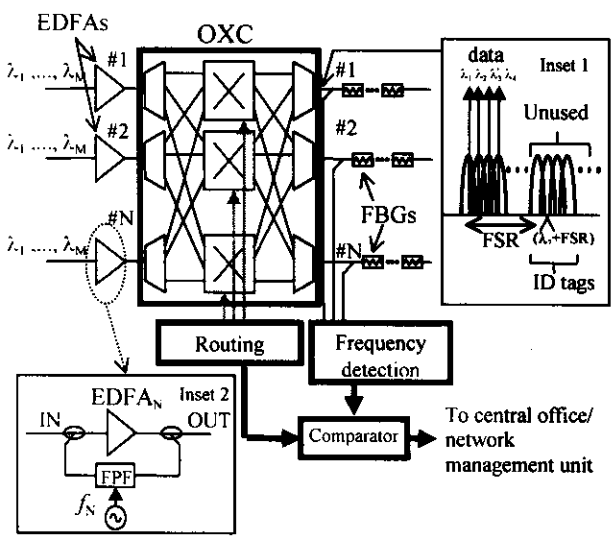

Fig. 3 Optical routing path supervisory scheme for AWG-based OXC.

(d) WDM Passive Optical Network

Passive optical network relies on wavelength routers to direct its WDM channels to its corresponding subscriber units. However, the router can be affected by temperature, causing a misalignment between router's passbands and the source wavelengths, thus generating data loss and neighboring channel crosstalk. Giles et al. [6] has proposed to place an FBG at the router node to reflect a probe wavelength to track the changes in the router passband. The generated error signal can then be used to adjust the optical sources or the wavelength router.

We have demonstrated a surveillance scheme with similar functionality [7]. The matching of the AWG-based router passband and the data wavelength is realized by placing a temperature-compensated FBG at one of the router output ports. Using the cross-over and periodicity properties of the AWG, the FBG reflects the input EDFA's ASE power at the cross-over wavelength of two adjacent router passbands (one FSR away from that of the data). Signals from both channels will be detected. The difference of the signals will generate an error signal, which will trigger a servo-control circuitry and adjust the corresponding temperature of the wavelength router so that data wavelengths and router passbands can be aligned.

Fiber break in an optically amplified branched passive optical network can be identified by placing an FBG at the end of each fiber branch to reflect the unused ASE power at the distinct FBG reflection wavelength [8]. The absence of a particular reflected ASE wavelength identifies the broken fiber branch.

(e) WDM Monitor

Giles et al. also demonstrated a WDM signal monitor based on concatenated FBGs with an electro-absorption optical modulator [9]. Input WDM signals are first pulse-modulated and then reflected by the FBGs. The reflected signal is detected in form of a series of pulses in time-domain, each corresponding to each wavelength component. Channel wavelength and power can be derived from the pulse power ratios.

SUMMARY

Performance monitoring is a necessary function in WDM networking elements and systems. With FBG, we have demonstrated that many such functions can be integrated in the physical layer, thus progressing towards in reducing the complexity in packet-based WDM networking layers. The use of FBG in surveillance is attractive and promising because of its low cost and its ease in integration into the networking elements and systems.

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